SCANNING EXPOSURE METHOD AND APPARATUS, AND DEVICE MANUFACTURING METHOD USING THE SAME

FIELD OF THE INVENTION AND RELATED ART

This invention relates generally to an exposure apparatus usable in a lithographic process, for example, for a semiconductor device or liquid crystal device. More particularly, the invention is concerned with a scan type exposure apparatus wherein a pattern formed on an original is transferred to a substrate to be exposed by relatively moving the original and the substrate relative to a projection optical system.

Exposure apparatuses for use in manufacture of semiconductor devices, for example, are currently represented by a step-and-repeat type exposure apparatus (stepper) wherein a substrate (wafer or glass plate9 to be exposed is moved stepwise so that a pattern of an original (reticle or mask) is printed on different exposure regions on the substrate in sequence and by sequential exposures with use of a projection optical system, and a step-and-scan type exposure apparatus (scan type exposure apparatus) wherein, through repetitions of stepwise motion and scanning exposure, lithographic transfer is repeated to different regions on a substrate. Particularly, in scan type exposure apparatuses, since only a portion

of a projection optical system close to its optical axis is used with restriction by a slit, higher precision and wider picture-angle exposure of a fine pattern can be accomplished. It will therefore become the main stream.

In conventional scan type exposure apparatuses, usually, global alignment procedure is made by using an off-axis alignment scope which is disposed in a scan axis direction as viewed from the optical axis of a projection optical system and, after moving a wafer to an exposure start point below the projection optical system (along the scan axis direction), stepwise motion and scanning exposure in regard to a next shot are repeated. In the movement or scanning motion of the wafer, laser interferometers are used to measure the position y of a wafer stage in the scan axis direction (hereinafter, Y direction) and the position x with respect to a direction (hereinafter, X direction) along a horizontal plane and being perpendicular to the scan axis direction as well as rotation θ (yawing) around a vertical axis (hereinafter, Z axis). On the basis of measured data, the wafer stage is servo-controlled. Usually, the yawing measurement for this servo-control is performed only in respect to a single direction, i.e., the scan axis direction.

SUMMARY OF THE INVENTION

The inventors of the subject application have found that: the yawing measurement data will theoretically be the same regardless that the measurement is made with respect to X direction or Y direction; comparing the results when yawing measurement in a scan type exposure apparatus is made in respect to X direction and when it is made in respect to Y direction, synchronization precision during scan is deteriorated where the yawing measurement is made in respect to X direction while overlay precision based on alignment precision in superposed printing is deteriorated where the yawing measurement is made in respect to Y direction, both as compared with a case where the stage servo control is made on the basis of the yawing measured value, measured with respect to the other direction, i.e., Y direction or X direction.

It is an object of the present invention to improve the performance of a scan type exposure apparatus such as synchronization precision in scan or overlay precision in superposed printing.

In accordance with an aspect of the present invention, there is provided a scan type exposure apparatus, wherein a pattern is transferred sequentially to different regions of a substrate through a step-and-scan operation including a

combination of stepwise motion of the substrate to an original and scanning exposure, moving the original and the substrate in a Y direction, said apparatus comprising: a stage for carrying a substrate thereon and being movable in the Y direction and an X direction orthogonal thereto; first measuring means for measuring yawing of said stage by using a first reflection surface along the Y direction of a mirror mounted on said stage; and second measuring means for measuring yawing of said stage by using a second reflection surface along the X direction of a mirror mounted on said stage.

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In one preferred form of this aspect of the present invention, said first and second measuring means include laser interferometers for projecting laser beams to the same reflection surface and for performing interference measurement based on reflected laser beams. One of the laser interferometers may be used in the first measuring means as an X-direction laser interferometer for measuring the stage position with respect to X direction, and also used in the second measuring means as a Y-direction laser interferometer for measuring the stage position with respect to Y direction.

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The stage movement may be servo controlled in accordance with the yawing measurement through the first or second measuring means. The first and second

measuring means may be selectively used in accordance with the state of operation of the exposure apparatus. For example, for scanning exposure in which scan is made in Y direction, the stage position measurement may be made by use of a Y-direction laser interferometer, a Y yawing measurement interferometer and an X-direction laser interferometer. Namely, for the scanning exposure, the second measuring means may be used for the yawing measurement. An alignment scope for performing an off-axis alignment measurement to the substrate may be used and, in that occasion, for the movement after the measurement by the alignment scope, the yawing measurement may be performed by use of the measuring means which is related to a direction orthogonal to the movement direction. Namely, when the measurement position of the alignment scope upon the stage is placed in Y direction as viewed from the optical axis of the projection optical system, for the movement after measurement by the alignment scope, the yawing measurement may be performed by use of the first measuring means, whereas when the measurement position of the alignment scope is placed in X direction as viewed from the optical axis of the projection optical system, the yawing measurement may be performed by use of the second measuring means.

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For the selective operation of the first and

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second measuring means, while they may be selectively operated in accordance with the state of operation of the exposure apparatus as described above, one of the measurement data of the them may be made effective. Alternatively, the measurement data of the first and second measuring means may be used through averaging processing or statistical processing.

In accordance with another aspect of the present invention, there is provided a scanning exposure method, comprising the steps of: preparing an original and a substrate; measuring a position of the substrate by use of an alignment scope and, after the measurement, moving the substrate; and sequentially transferring a pattern of the original to different regions on the substrate in accordance with a step-and-scan operation including a combination of stepwise motion of the substrate relative to the original and scanning exposure while moving the original and the substrate; wherein, between the scanning exposure and the movement after measurement by the alignment scope, a measurement direction with respect to which yawing measurement to a stage using a laser interferometer is made different. For example, for the scanning exposure, the stage yawing measurement may be performed by projecting laser beams in a direction the same as the scanning movement direction, while, for movement after the measurement by the alignment scope,

the stage yawing measurement may be performed by projecting laser beams in a direction orthogonal to the movement direction.

In accordance with a further aspect of the present invention, there is provided a scanning exposure method, comprising the steps of: preparing an original and a substrate; measuring a position of the substrate by use of an alignment scope and, after the measurement, moving the substrate; and sequentially transferring a pattern of the original to different regions on the substrate in accordance with a step-and-scan operation including a combination of stepwise motion of the substrate relative to the original and scanning exposure while moving the original and the substrate; wherein, for the scanning exposure, yawing measurement to a stage is performed by using a laser interferometer and in relation to a direction the same as the scanning movement direction, and wherein, for the movement after measurement by the alignment scope, yawing measurement to the stage is performed by using a laser interferometer and in relation to a direction orthogonal to the movement direction.

The inventors of the subject application have found that, in a scan type exposure apparatus, the flatness and orthogonality of bar mirrors for interferometer measurements have the following influences:

(1) When stage servo control is made in respect to the yawing direction on the basis of an interferometer having a measurement axis orthogonal to the scan axis, the flatness of a bar mirror leads to stage external disturbance, causing degradation of synchronization precision during the scan.

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(2) Where automatic global alignment (AGA) is performed by use of an off-axis alignment scope which is positioned in the scan axis direction as viewed from a projection optical system, as in conventional systems, and when stage servo control is made in the yawing direction on the basis of an interferometer in the same direction as the scan axis, a change in orthogonality of bar mirrors between the AGA operation and the scanning exposure operation will cause degradation of overlay precision. This is because of a shift corresponding to the baseline (distance between the alignment scope position and the optical axis of the projection optical system) as multiplied by the change in orthogonality ($\sin\Delta\theta$).

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In accordance with the present invention, there are yawing measuring means in relation to both of X and Y directions, and they may be used selectively in accordance with the state of operation of the exposure apparatus. This enables significant improvements of various performances, such as overlay precision and synchronization precision.

These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of a scan type exposure apparatus according to an embodiment of the present invention.

Figure 2 is a perspective view of a scan type exposure apparatus according to another embodiment of the present invention.

Figure 3 is a flow chart for explaining microdevice manufacturing processes.

Figure 4 is a flow chart for explaining a wafer process included in the procedure of Figure 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

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Figure 1 shows a scan type exposure apparatus according to an embodiment of the present invention. Denoted in the drawing at 1 is a reticle, and denoted at 3 is a wafer. Denoted at 2 is a projection optical system for projecting a pattern of the reticle 1 onto the wafer 3. Denoted at 4 is a wafer stage for performing X-Y drive and tilt drive of the wafer 3,

and denoted at 5 is a stage base on which the wafer stage 4 is mounted. Denoted at 6 is a Y-direction laser interferometer for measuring the position y in Y direction (Y coordinate) of the wafer 3 by using a laser beam related to the Y direction. Denoted at 7 is a Y yawing measurement interferometer (second yawing measuring means) for detecting any rotation (yawing) θy about Z axis as the wafer stage 4 moves, in cooperation with the Y-direction laser interferometer 6 and by using the Y-direction laser beam. Denoted at 8 is an X-direction laser interferometer for measuring X-coordinate x of the wafer 3 by use of a laser beam related to the X direction. Denoted at 9 is an X yawing measurement interferometer (first yawing measuring means) for detecting any rotation (yawing) θx about Z axis as the wafer stage 4 moves, in cooperation with the X-direction laser interferometer 8 and by using the X-direction laser beam.

Denoted at 10 is a Y bar mirror having a second reflection surface along the X direction, for reflecting laser beams from the Y-direction laser interferometer 6 and the Y yawing measurement interferometer 7. Denoted at 11 is an X bar mirror having a first reflection surface along the Y direction, for reflecting laser beams from the X-direction laser interferometer 8 and the X yawing

measurement interferometer 9. These two bar mirrors 10 and 11 may be provided by a single mirror member with orthogonal reflection surfaces (having the function of X and Y bar mirrors), without separating them. Denoted at 12 is an off-axis alignment scope for performing off-axis wafer alignment. Denoted at 20 is a control unit for controlling various units of this embodiment as described above, and the control unit is communicated with these units via communication lines, not shown. The control unit 20 may be provided by a computer controlled system. Various functions of this embodiment may be performed in accordance with programs stored in the control unit 20. Denoted at A is the scan direction of the reticle 1 for the scanning exposure operation. Denoted at B is the scan direction of the wafer 3. Denoted at θ is the yawing direction of the stage 4. Idealistically, there is a relation $\theta y = 0 = \theta x$.

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In the exposure apparatus illustrated, the alignment scope 12 is disposed in the scan direction (Y direction) of the projection optical system 2 and, as compared with conventional scan type exposure apparatuses wherein the yawing measurement to the stage 4 is performed in the scan axis direction and by using the Y-direction laser interferometer 6 and the Y yawing measurement interferometer 7, there is X yawing measurement interferometer 9 added which is operable

to perform yawing measurement to the stage 4 in X direction in cooperation with the X-direction laser interferometer 8. During the scan exposure operation, as conventional, the yawing measurement is performed in Y direction by using the laser interferometers 6 and 7, whereas for the global alignment (AGA) operation, it is performed in X direction by using the laser interferometers 8 and 9. The two laser interferometer systems are selectively used in this manner.

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Thus, during scan operation, the Y bar mirror 10 functions to perform yawing measurement approximately at a constant position. Thus, there is small influence of the flatness of the bar mirror, and the synchronization precision is not degraded. For the global alignment operation, there is small influence of the orthogonality of the X bar mirror 11 to the Y bar mirror 10 and, therefore, the overlay precision is improved as compared with that of conventional scan type exposure apparatuses.

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Further, in the exposure apparatus of Figure 1, in the states of operation other than the alignment operation or scanning operation, measurement may be performed on the basis of a side more convenient to the state of operation being done, or the yawing measured data more convenient may be used selectively. As a further alternative, both of the measured data

may be used on the basis of averaging processing or through statistical processing. The measuring means may be used selectively, in this manner.

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Figure 2 shows a scan type exposure apparatus according to another embodiment of the present invention. Those components corresponding to that of the Figure 1 embodiment are denoted by like numerals. In the exposure apparatus of Figure 2, as compared with conventional apparatuses described above, the position of the alignment scope 12 with respect to the projection optical system 2 is placed in X direction (Figure 2), this being to be contrasted to Y direction in the conventional structure. With this arrangement, the movement direction in the alignment direction is laid on X direction which is orthogonal to the scan axis direction (Y direction). Even though the same laser interferometers 6 and 7 are used for yawing measurement in Y direction, the yawing measurement direction (Y direction) in alignment operation is preferably laid on a direction orthogonal to the movement direction (X direction). As a result, without degradation of synchronization precision, the overlay precision can be improved.

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In the exposure apparatus of Figure 2, there is an X yawing measurement interferometer 9 added, for performing yawing measurement to the stage 4 in X direction, in cooperation with the X-direction laser

interferometer 8. In accordance with the state of operation other than the alignment operation or scan operation, the yawing data measured with respect to the direction convenient may be selected or the measurement may be switched. Alternatively, both of the yawing measured data may be used through averaging processing or statistical processing.

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Next, an embodiment of a device manufacturing method which uses an exposure apparatus as described above, will be explained.

Figure 3 is a flow chart of procedure for manufacture of microdevices such as semiconductor chips (e.g. ICs or LSIs), liquid crystal panels, CCDs, thin film magnetic heads or micro-machines, for example.

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Step 1 is a design process for designing a circuit of a semiconductor device. Step 2 is a process for making a mask on the basis of the circuit pattern design. Step 3 is a process for preparing a wafer by using a material such as silicon. Step 4 is a wafer process which is called a pre-process wherein, by using the so prepared mask and wafer, circuits are practically formed on the wafer through lithography. Step 5 subsequent to this is an assembling step which is called a post-process wherein the wafer having been processed by step 4 is formed into semiconductor chips. This step includes assembling (dicing and

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bonding) process and packaging (chip sealing) process. Step 6 is an inspection step wherein operation check, durability check and so on for the semiconductor devices provided by step 5, are carried out. With these processes, semiconductor devices are completed and they are shipped (step 7).

Figure 4 is a flow chart showing details of the wafer process.

Step 11 is an oxidation process for oxidizing the surface of a wafer. Step 12 is a CVD process for forming an insulating film on the wafer surface. Step 13 is an electrode forming process for forming electrodes upon the wafer by vapor deposition. Step 14 is an ion implanting process for implanting ions to the wafer. Step 15 is a resist process for applying a resist (photosensitive material) to the wafer. Step 16 is an exposure process for printing, by exposure, the circuit pattern of the mask on the wafer through the exposure apparatus described above. Step 17 is a developing process for developing the exposed wafer. Step 18 is an etching process for removing portions other than the developed resist image. Step 19 is a resist separation process for separating the resist material remaining on the wafer after being subjected to the etching process.

By repeating these processes, circuit patterns are superposedly formed on the wafer. With

these processes, high density microdevices can be manufactured.

While the invention has been described with reference to the structures disclosed herein, it is not confined to the details set forth and this application is intended to cover such modifications or changes as may come within the purposes of the improvements or the scope of the following claims.